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MANAGEMENT PROCEDURE OF SUPPLIES OF UNITS, MATERIALS AND CONSTITUENT PARTS FOR REPAIR AND MAINTENANCE SUPPORT OF TRANSPORT AND PRODUCTION MACHINES

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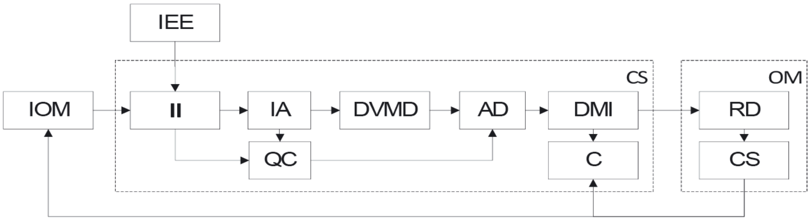
This article considers a question of creation of schemes and sequence of passing of the main stages of process of execution of repair and maintenance works order taking into account formation of stocks of necessary spare parts, materials and constituent parts. Models of an input stream are offered for inventory control system, which are rather adequately described by autoregressive models of order two.

Keywords: *Transport machines; maintenance support; repair; inventory models; random processes; autocorrelation.*

1. Introduction

Any auto-transport enterprise (ATE) represents system, i.e. set of interrelated and interacting components. In it move material, financial and information streams. Various external factors influence it. At the same time management process has cyclic character and contains a lot of stages (pic. 1). Management process – is the impact on the system and its components, which ensures its effective functioning.

The main stages are: processing of initial information (II) on object of management (IOM) and external environment (IEE), information analysis (IA) and choice of quality criteria (QC), development of variants for management decisions (DVMD), adoption of management decision (AD), development of the managing instruction (DMI). In object of management carried out realization of the adopted decision (RD), as a result of which there is a change in a state of an object of management (CS). Change in a state of the object of management (OM) is controlled in the control system (CS) in the control block (C), in which parameters of the changed state of object of management are compared with parameters reflected in the managing instruction.



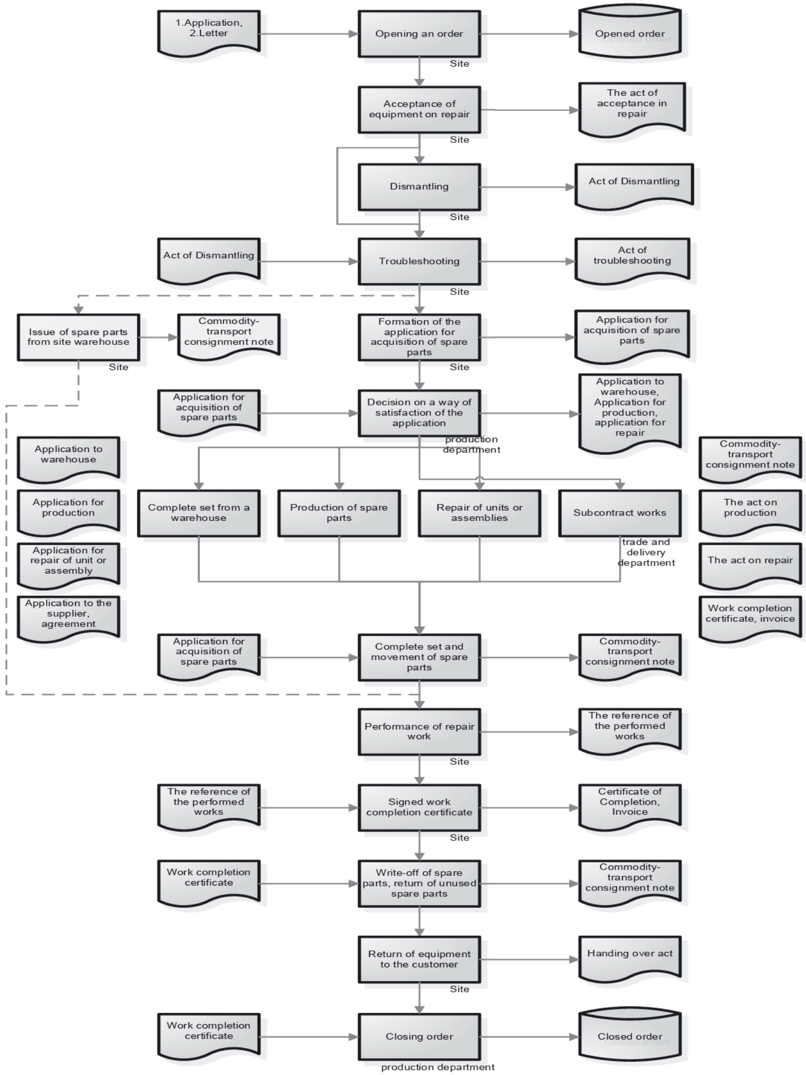
Pic. 1. Stages of management process

2. Order of execution of repair and maintenance support (MS)

In article is offered the order of execution and the scheme of technological process on repair and maintenance support of transport and technological machines (pic. 2), the main result of which is timely and qualitative execution of the order.

When opening the order the required repair is estimated and is appointed a person responsible for execution (job foreman). Then stage acceptance of equipment, which marks opening of the order number and the required repairs. Main result of a stage is dismantling - equipment of the customer sorted on units. Function is carried out only in case of capital repairs. For the current and emergency repair troubleshooting step runs immediately, which main result is the list of the knots and details demanding replacement or repair.

Stage 5 is performed only in case of availability of the necessary parts on site warehouse. In case of lack of necessary spare parts the stage formation of the application for acquisition of spare parts is carried out, which result is the application for acquisition of spare parts transferred to production department. With it stages 6, 7, 8, 9, 10, 11 and 12 are carried out only in case of lack of necessary spare parts in a site warehouse. In the case of availability of the necessary parts in a warehouse of a site the stage 5, and then 13 is carried out (conduct repairs).



Pic. 2. Order of execution and the scheme of technological process of execution of the main order on repair of equipment

As a result of the execution of 7-th stage formed application for warehouse, manufacturing, repair of units or application to the supplier on performance of subcontract works. Also preparing a list of units and assemblies that need to be repaired by the forces of MRD [mechanical repair department] (stage 9). Stage 8 – the result: spare parts issued to repair from the central warehouse. In case of lack of necessary spare parts in the central warehouse at first the “purchase of CM [commodities and materials]” procedure is carried out. As a result of performance of the 10th stage the repaired units and assemblies indulge to assembly shop. Stage 11 to repair units and assemblies involves engaging a third-party organization. The result of stage 12 is a full set of spare parts required for repairs, moved on a site. The result of stage 13 is repaired equipment of the customer, then signed work completion certificate. Procedures of write-off and return of unused spare parts to the central warehouse are also possible.

3. Inventory models

In work it is shown that both the input stream model and random inventory process is rather adequately described by autoregression models, which represents a sequence of random variables x_1, x_2..., satisfying to the stochastic differential equation at existence of a linear combination:

$$\xi_t + \beta_1 \times \xi_{t-1} + \ldots + \beta_p \times \xi_{t-p} = \varepsilon_t \quad t=1+p,\ldots, \tag{1}$$

where the sequence ε_{p+1}, ε_{p+2}, ... is a sequence of the independent and equally distributed random variables.

The simplest case is a first-order equation $\xi_t = -\beta_1 \times \xi_{t-1} + \varepsilon_t$. Autocorrelated function of such process is equal $r(t) = \sigma^2 \frac{(-\beta_1)^t}{1-\beta_1^2}$. However, such process doesn’t allow to realize “circuity” of autocorrelated function (ACF). In this regard in work is offered using models of second order autoregressive process $\xi_t = -\beta_1 \times \xi_{t-1} - \beta_2 \times \xi_{t-2} + \varepsilon_t$.

For aperiodic processes in the case of real roots of the characteristic equation autocovariance function has the form

$$r(t)=\frac{\sigma^2}{(x_1-x_2)(1-x_1x_2)}\left(\frac{x_1^{t+1}}{1-x_1^2}-\frac{x_2^{t+1}}{1-x_2^2}\right), \qquad (2)$$

where $0<x_1<1$ и $0<x_2<1$. Such models of 2nd order autoregressive process gives the opportunity of modeling of non-stationary processes with possibility to task an initial dynamics of process development, that is necessary for implementation of enterprise development models during the transition to new forms of management.

The carried-out analysis of input streams and the received models of orders volume allow approaching the solution of a problem of modelling inventory effectiveness. In work two models are considered: the management model with a fixed range and model monotonous policy of ordering.

In a case of model with fixed range set two threshold values: *s* and *S*, $0\le s<S<\infty$. With destocking to s, produced an order to the effect, that level has risen to *S*. As a result, the volume of the order is calculated as

$$\eta_{n+1}=\begin{cases}0, & s\le Z_n\le S\\ S-Z_n, & Z_n<s\end{cases}. \qquad (3)$$

At the same time total stock for this model is calculated on the basis

$$Z_{n+1}=\begin{cases}Z_n-\xi_{n+1}, & s\le Z_n\le S\\ S-\xi_{n+1}, & Z_n<s\end{cases}. \qquad (4)$$

In the given model, the ordered volume of accessories is delivered always, however some casual delay is possible. In the context of modelling is interesting the situation when the volume of deliveries also represents a set of random variables.

In the case of monotonous policy also determines critical value x^* and as soon as the level of a stock becomes less than this value

(Z_n<x*), procedure of the order with immediate delivery of casual volume of units and spare parts X_{n+1} is carried out. The law of distribution is considered as set, and the recurrence relation for modeling of volume of stocks is defined as

$$Z_{n+1} = \begin{cases} Z_n + X_{n+1} - \xi_{n+1}, & Z_n < x^* \\ Z_n - \xi_{n+1}, & Z_n \geq x^* \end{cases} \tag{5}$$

where ξ_{n+1} – requirement of accessories.

It is shown that both inventory and input streams models can be rather adequately presented by processes of autoregression of the 2nd order. Dependence (2) for autocorrelated function of process of autoregression by replacement of variables $x_1 = e^{-c_1}$, $x_2 = e^{-c_2}$ is given to a look

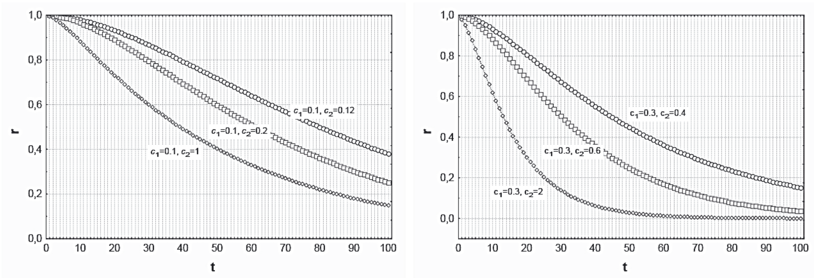
$$r(t) = \sigma^2\left(\alpha_1 e^{-c_1 t} + \alpha_2 e^{-c_2 t}\right), \tag{6}$$

where $c_1>0$ and $c_2>0$ autocovariance parameters, $\alpha_1 = \dfrac{e^{-c_1}(1-e^{-2c_2})}{e^{-c_1}(1-e^{-2c_2}) - e^{-c_2}(1-e^{-2c_1})}$ and α_2 (defined similarly) – functions of parameters c_1 and c_2. The received approximation (6) includes exponential as a special case.

Varying the specified parameters, it is possible to model quite wide class of autocorrelations. Pic. 3. shows graphs of autocorrelation functions obtained by different combinations of the values of c_1 and c_2 parameters.

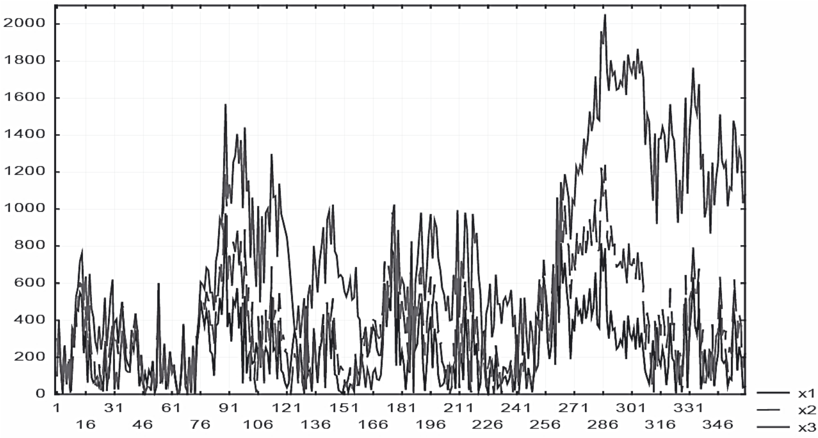
As a result of the carried-out analysis it is possible to draw the following conclusions: minimum from parameters c_1 and c_2 determines length of an interval on which correlation is essential. The difference between parameters c_1 and c_2 defines a type of ACF at small values t. The smaller the difference, the flatter the beginning autocovariance. Apparently, from graphs, varying the c_1 and c_2 parameters, it is possible to achieve a big variety in behaviour of function.

For various characteristics of processes time ranks were simulated (Pic. 4). It can be seen that the received ranks have rather various character what autocorrelated function indicates (Pic. 5).

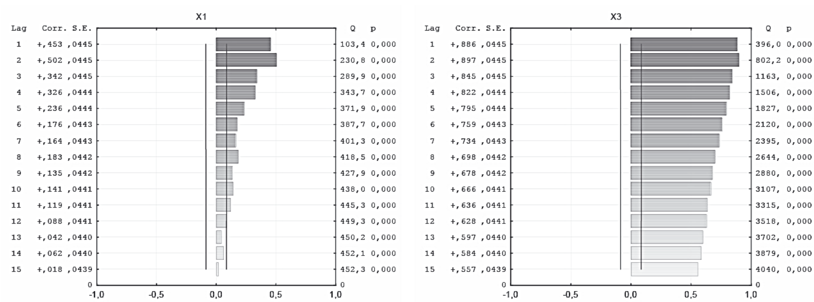


a) **b)**

Pic. 3. Approximation of ACF



Pic. 4. Selective trajectories of time ranks of autoregression



a) rank x1 **b)** rank x1

Pic. 5. Autocorrelated functions of time ranks

As a result of carrying out experiments on modelling and an assessment of characteristics of resultant processes it is shown that the received models rather adequately correspond to initial temporary ranks for the surveyed car repair enterprises.

4. Task of optimization of reservation

The optimized system is considered as set *N* types of not redundant replaceable modules, for each of which set the cost of one module (*w*), and also value of intensity of sudden refusal in disable (λ0) and enable (λ1) state. The system is characterized by the total cost (*W*) and probability of prosperity, with spare parts (*P*) at the known times of finding of system in disable (*t*0) and enable (*t*1) states.

In work two statements of an optimizing task are considered.

Task 1. To find the number of spare modules of each type (*z*) for minimization of cost of spare parts at limited probability of providing by SPA [spare parts and accessories]:

$$\begin{cases} \vec{z} = \arg\min(\vec{w} \cdot \vec{z}) \\ P \geq Pz \end{cases}, \tag{7}$$

where *Pz* – pre-set value of probability of providing by SPA.

Task 2. To find the number of spare modules of each type (*z*), for maximizing probability of providing by SPA at the limited cost:

$$\begin{cases} \vec{z} = \arg\max(P) \\ \vec{w} \cdot \vec{z} \leq Wz \end{cases}, \tag{8}$$

where *Wz* – pre-set value of SPA cost.

In tasks (7) and (8) probability of prosperity of the system by SPA is:

$$P = \prod_{n=0}^{N-1}\left[e^{-s_n}\left(1 + \sum_{m=1}^{z_n}(s_n)^m \Big/ m!\right)\right], \tag{9}$$

where $s_n = (\lambda 0_n \cdot t0 + \lambda 1_n \cdot t1) \cdot x_n$; x_n – number of *n*-type modules (without taking into account SPA) in the system; λ_{0n}, λ_{1n} – failure rate of the *n*-type module.

Tasks (7) and (8) belong to the class of nonlinear integer optimum tasks with non-negative arguments and are characterized by the following features:

– with taking the logarithm of expression (9) tasks can be brought to a separable look;
– if for system in the whole P≥Pz, then this condition is fair also for each type of the modules which forming the system.

The task of optimization is brought to iterative procedure of consecutive calculation of functions

$$f(z,s,w)=w^{-1}\cdot\left\{\mathit{ln}\left[1+\sum_{m=1}^{N-1}\left(s^m\ /\ m!\right)\right]-s\right\}. \quad (10)$$

On each iteration of procedure the priority direction is defined with restrictions:

$$nopt=\arg\max\{f(z+1,s_n,w)-f(z,s_n,w)\}. \quad (11)$$

Calculations for various combinations of reservation of spare parts from the point of view of two objectives were carried out.

5. Conclusion

Is offered technique of optimization of preventive replacements allowing to put down expenses and to raise a ready state of transport and technological machines. Formed the order of passing and the scheme of technological process of execution of the main stages of the order for maintenance supply and repair that integrates models of realization of a production cycle. Developed models of input streams and recurring inventory process schemes, which for the chosen policy of formation of a package of applications for certain types of spare parts, materials and accessories allow to estimate probabilities of refusals.

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